("cw") mode-locking evolving from Q-switched mode-locking (QSML). In contrast, the mode-locking of most solid state lasers begins from cw noise. Mode-locking is one of the most important modes of operation for a laser. When a laser is mode-locked, the optical energy is compressed into a very short pulse of about a few picoseconds. Q-switching is a means of obtaining short intense pulses from lasers. The Q-switch inhibits lasing until a very large inverted population of excited atoms builds up. However, if the application requires a continuous wave, persistent Q-switching would be troublesome.

In addition, this invention may include the use of interactivity Resonant Fabry-Perot Absorbers (R-FPSA) for inducing self-starting mode-locking in a laser. An optical power limiter such as a two photon absorber (TPA), e.g., a semiconductor material, is optionally used in the laser cavity to inhibit Q-switching. The R-FPSA may be designed such that the nonlinear loss experienced by the saturable absorber is enhanced over the prior art Anti-resonant Fabry-Perot saturable absorber (A-FPSA) configurations. The TPA power limiter provides effective damage protection for the R-FPSA and self-adjusts the total nonlinear loss of the laser to be in the stable cw mode-locking region. The suppression of Q-switching leads to laser output that is cw mode-locked.

Prior to this invention, semiconductor saturable absorbers have found application in the field of passively mode-locked, ultrashort pulse lasers. These devices are attractive since they are compact, inexpensive, and can be tailored to a wide range of laser wavelengths and pulsewidths.

Prior to this invention, a cw mode-locked laser with Q-switching suppression was not known. Thus, this invention is the first cw mode-locked laser which generates Q-switched mode-locked laser pulses and then suppresses the Q-switching.

The R-FPSA may include two reflectors having a defined spacing. One reflector is preferably a maximum reflector that defines one end of the laser cavity (the "end reflector"), whereas the other reflector is formed by a high or partial reflector that faces the gain medium of the laser (the "inner reflector").

When the Fabry-Perot device has a defined thickness leading to a double pass phase change equaling $\delta=(2m+1)\pi$, where m is a positive integer, the Fabry-Perot structure is said to be at resonance. In this case, the fraction of the intercavity power that is reflected from the saturable absorber($R_{F\text{-}P}$) is a minimum. By operating at resonance, the laser intensity absorbed by the

saturable absorber is enhanced. By operating the Fabry-Perot device at resonance, the intensity absorbed by the saturable absorber is increased by a substantial factor.

The effect of varying R on $R_{F\text{-}P}(\lambda)$ for an R-FPSA is illustrated in FIGURE 2 of the application. The spacing between adjacent minima is preferably large for certain applications such as ultrafast lasers, where broad bandwidth is needed. The inner reflector should have a reflectivity R sufficiently high to provide a desired intensity on the saturable absorber. This reflectivity R, however, should not be so high that $R_{F\text{-}P}(\lambda)$ is no longer relatively flat over the gain profile. For example, if the inner reflector reflectivity R is too high, the bandwidth of $R_{F\text{-}P}(\lambda)$ at resonance needed for mode-locked laser pulses may be too limited. For applications in which the spot size on the saturable absorber can not be varied (e.g., butt-coupling to a fiber or a waveguide), "tuning" the intensity on the absorber by selecting an appropriate R may be desirable.

The resonant effect on the nonlinear loss and $R_{F\text{-}P}$ as a function of wavelength is explored in FIGURE 3 of the application. This figure shows that the nonlinear loss experiences a significant enhancement when the Fabry-Perot device is designed to be at resonance. It can be seen by using the appropriate equation that the nonlinear loss at resonant (near 1540 nm) is 7 times larger than that at anti-resonance.

In one preferred embodiment, the gain medium is an erbium doped fiber having an upper state lifetime on the order of milliseconds (ms), and the round trip cavity time is typically 10-100 nsec. By using an R-FPSA with a large nonlinear loss, the fiber laser may operate in a QSML regime rather than a cw mode-locked regime. In this case, it may be necessary to suppress the intense Q-switched pulses, thereby driving the laser below threshold. In a preferred embodiment of this invention, a two photon absorber (TPA) is used for this purpose to complement the R-FPSA, so that the laser operates in a cw mode-locked regime. The TPA preferably has little or no single photon absorption at the laser wavelength. Thus, two different types of absorbers, having different nonlinear behavior, may be used in the same device to achieve self-starting, cw mode-locked behavior.

The different intensity dependencies of a preferred saturable absorber (InGaAsP) and a preferred two photon absorber (InP) are illustrated in FIGURE 4 of the application. The loss due to the two photon absorber increases strongly as a function of intensity, whereas the loss due to the

saturable absorber decreases (saturates) with increasing intensity. The resultant "V-shaped" total loss of FIGURE 4 has a minimum which is a favorable regime for cw mode-locking.

The optical limiter (e.g., the TPA) preferably has a large two photon absorption coefficient β_2, which is a function of the ratio of the material's band gap E_g and the photon energy (see, for example, E. W. Van Stryland, M. A. Woodall, H. Vanherzeele, and M. J. Soileau, Energy band-gap dependence of two-photon absorption, *Opt. Lett.*, 10, 490, 1985). FIGURE 5 of the application shows how the two photon coefficient scales with this ratio. For a given laser wavelength, the band gap E_g of the optical power limiter may be larger than the photon energy , so that maximum two photon absorption can be obtained without significant increase in the insertion loss, *l*. The band gap can be easily controlled by proper choice of the semiconductor material and/or its doping levels.

The TPA is effective at suppressing QSML regardless of its position in the laser cavity. For example, the TPA may adjoin the saturable absorber. Alternatively, the TPA and the saturable absorber may be located on opposite sides of the gain medium, or several TPAs may be used to reduce the thickness of the Fabry-Perot device, thereby offering greater design flexibility.

Suppression of Q-switched pulses by two photon absorbers has been previously reported (see, for example, A. Hordvik, Pulse stretching utilizing two-photon-induced light absorption, *J. of Quantum Electronics*, QE-6, 199 (1970) and V.A. Arsen'ev, I. N. Matveev, and N. D. Ustinov, Nanosecond and microsecond pulse generation in solid-state lasers (review), *Sov. J. Quantum Electron*, vol. 7 (11), 1321 (1978)). Also, semiconductor-based two photon absorbers have been used as optical power limiters to protect damage sensitive optics (see, for example, U.S. patent 4,846,561 to Soileau et al.).

The band gap of a two photon absorber lies well above the photon energy at the laser wavelength, so that single photon absorption is low at low intensities. At higher intensities, however, the production rate of carriers generated from the valance band to the conduction band increases.

A two photon absorber tends to limit the pulse shortening of high intensity pulses, since pulse peaks are more strongly attenuated than the wings. Thus, the conventional understanding of the two photon absorption effect is that it degrades the performance of mode-locked lasers (see, for

example, A. T. Obeidat and W. H. Knox, Effects of two-photon absorption in saturable Bragg reflectors in femtosecond solid-state lasers, *OSA Technical Digest*, 11, 130, Proceedings of CLEO' 97). In the high gain fiber laser disclosed herein, however, Q-switched mode-locking is the main impediment to cw mode-locking. Thus, by suppressing QSML, this invention facilitates cw mode-locking.

The combination of the R-FPSA and the TPA optical limiter disclosed in the application provides one arrangement for self-starting mode-locking, since the R-FPSA provides quick pulse shortening due to its large saturable loss, and the optical limiter self adjusts the nonlinear loss to be within the cw mode-locking stability region (FIGURE 4 in the appplication). The TPA power limiter also provides effective damage protection for the saturable absorber. The intensity on the saturable absorber can be optimized by varying the spot size on the absorber, or by selecting R appropriately.

Response to the Examiner's rejections

35 U.S.C. 112 REJECTION

The Examiner rejected Claims 22-28 and 33-34 under 35 U.S.C. 112, paragraph 2. The Examiner found these claims to be indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Specifically, the Examiner rejected the claims as being incomplete for omitting essential steps, such omission amounting to a gap between the steps. The Examiner identified the omitted steps as: (1) pumping a gain medium within a resonant Fabry-Perto laser cavity; (2) generating Q-switched mode-locked laser pulses using a saturable absorber located within said resonant Fabry-Perot optical cavity; (3) absorbing said Q-switched laser pulses by insertion of a Two-Photon Absorber within said resonant Fabry-Perot optical cavity; and (4) outputting a cw mode-locked laser pulse from said resonant Fabry-Perot optical cavity. The Examiner stated that these steps are essential because they (1) are necessary to generate a cw mode-locked laser pulse as disclosed by the applicant and (2) these steps are not obvious to someone of skill in the art of lasers, as related to claim interpretation, without reference to the specification. In addition, the Examiner states that it is unclear from the claim language how a cw mode-locked laser pulse is generated with the claim steps. Specifically, the Examiner states that it is not clear what function the steps have as related

to the generation of the cw mode-locked laser pulses. As to Claim 23, the Examiner states that it is unclear from the claim language how the claimed invention is q-switched and q-switch suppressed.

First, as to the objection based on the omission of essential steps (MPEP 2172.01), MPEP § 2172.01 states:

> "A claim which omits matter disclosed to be essential to the invention as described in the specification, or in other statements of record may be rejected under 35 U.S.C. 112, first paragraph, as not enabling. *In re Mayhew,* 527 F.2d 1229, 188 USPQ 356 (CCPA 1976). See also MPEP 2164.08(c). Such essential matter may include missing elements, steps or necessary structural cooperative relationships of elements described by the applicant(s) as necessary to practice the invention.
>
> "In addition, a claim which fails to interrelate essential elements of the invention as defined by applicant(s) in the specification may be rejected under 35 U.S.C. 112, second paragraph , for failure to point out and distinctly claim the invention See *In re Venezia,* 530 F.2d 956, 189 USPQ 149 (CCPA 1976); *In re Collier*, 397 F.2d 1003, 158 USPQ 266 (CCPA 1968)." **(Emphasis added.)**

Under the language of MPEP 2172.01, as emphasized above, the applicant is only obliged to claim elements that were defined to be essential in the specification or in other statements of record. Applicants did not disclose in the specification, or in any other statement of record, that these steps were "essential." In *Mayhew*, the court ruled one step to be essential. There the court pointed to specific language of importance. "Appellant's specification states that the 'strip...and bath...are raised in temperature above what is ordinarily considered optimum coating temperatures. This is practicable because of special cooling apparatus, specially located.'" *Mayhew*, 527 F.2d at 1233. The above language of the application in that case made it clear that the element was essential to the invention. In the present application, there was no such language regarding any of the elements the Examiner regards as omitted essential elements. It is noteworthy that a second group of claims in the *Mayhew* patent were also rejected because of omission of an essential element, namely the specific temperature and functions of the cooling

zone. The *Mayhew* court overturned this second rejection of claims. The court reasoned that a person of ordinary skill in the art could determine the appropriate temperature and functions for the cooling zone based on the specification and particular uses with the patented process. *Mayhew,* 527 F.2d at 1233-1234.

A similar rationale should be applied to this application. The overarching essential steps are those steps that a person of ordinary skill would not do. Here, those steps are the suppression of Q-switching to generate cw mode-locked laser pulses. That is the new step that was introduced by these inventors, and that is what is claimed by the application. The alleged omitted essential steps are steps that anyone of ordinary skill in the art would recognize. First, those of ordinary skill would know that many lasers have a gain medium in the laser cavity, and would know how to build the same. The next two "omitted" elements go to the generation and suppression of Q-switching. Q-switching is a topic that has been covered thoroughly in both scholarly work and patents, and the generation of Q-switched laser pulses is something that a person of ordinary skill could accomplish in a number of ways. See, for example, Kajava, et. al. Q-switching of a diode-pumped Nd:YaG laser with GaAs, *Optics Letters*, Vol. 21, No. 16, August 15, 1996, pgs. 1244-1246 and Everett, Laser mode-locking, Q-switching and dumping system, Patent number 4,375,684 (1983). The suppression of Q-switching is taught by one of the references the Examiner cites, the Hordvick reference. While there may be several other ways to accomplish this task, the fact that one of these methods is clearly prior art should be sufficient to ensure that this task could be accomplished by a person of ordinary skill in the art. Finally, the Examiner argues that "outputting a cw mode-locked laser pulse from the said resonant Fabry-Perot optical cavity" is another omitted essential element. Output of a laser pulse from within the optical cavity, once such a pulse is generated, is a topic that is surely understood by anybody of ordinary skill in the field. See, for example, Ichinose, et. al., High power multibeam laser, Patent number 3,943,461 (1976). All of these "essential" elements are steps that are known to persons of ordinary skill in the art and are possible features of the invention claimed here, but they are not essential to the invention. In sum, the "essential" elements that were used to reject claims are comparable to the temperature and function rejections in *In re Mayhew*, and like those rejections, should be withdrawn.

In addition, the long-term viability of the *In re Mayhew* decision's "essential elements" ground is not clear. The case is rarely cited for this principle, and the cases on which the majority relies do not clearly support the decision. The majority cites only five cases, all of which overturn at least some of the original §112 indefiniteness rejections. *In re Borkowski*, 422 F.2d 904, 164 USPQ 642 (1970); *In re Moore*, 439 F.2d 1232, 169 USPQ 236 (1971); *In re Sarett*, 327 F.2d 1005, 140 U.S.P.Q. 474 (1964); *In re Corr*, 347 F.2d 578, 146 U.S.P.Q. 69 (1965); *In re Honn*, 364 F.2d 454, 150 U.S.P.Q. 652 (1966). In *Moore,* the court explained how a claim must be interpreted for definiteness:

> "This first inquiry therefore is merely to determine whether the claims do, in fact, set out and circumscribe a particular area with a reasonable degree of precision and particularity. It is here where the definiteness of the language employed must be analyzed - not in a vacuum, but always in light of the teachings of the prior art and of the particular application disclosure as it would be interpreted by one possessing the ordinary level of skill in the pertinent art." *Moore,* 439 F.2d at 1235.

This test does not clearly support the rule in *Mayhew*, as applied by the Examiner. Indeed, *Mayhew* seems to decide the case on a rule that the precedents cited do not clearly support.

In *Microsoft v Reiffin,* 214 F.3d 1342; 54 U.S.P.Q.2D (BNA) 1915, the Federal Circuit panel avoided the question of whether there is such an "essential element" test and decided the case on other grounds. See also, Donald S. Chisum, 6 <u>Chisum on Patents</u> § 7.04[2] (2001). However, in concurrence, Judge Newman felt that the question was ripe in the case and that the validity of the "omitted element" test was questionable. As Judge Newman stated:

> "The district court accepted Microsoft's proposition that the patentee must include in every claim "each and every element" that was described as "part of his invention," whether or not the element is necessary for patentability of the claim. Failure to do so, the district court held, invalidates the claims for noncompliance with the written description requirement of § 112 P[aragraph] 1. That is not a correct statement of the law. Section 112 P[aragraph]2 instructs the applicant to "distinctly claim[] the subject matter which the applicant regards as his invention." This does not automatically require

inclusion in every claim of every element that is part of the device or its operation." *Microsoft*, 214 F.3d at 1347.

The "omitted element" test is based on questionable precedents and unclear decisions.. Other cases that have been used to support the test do not really go to the question of whether every element of an invention needs to be claimed. For example, Microsoft cited *Gentry Gallery, Inc. v. Berkline Corp.*, 134 F.3d 1473, 45 U.S.P.Q.2d (BNA) 1498 (Fed. Cir. 1998) in order to support their contention that all elements of an invention need to be claimed. *Microsoft*, 214 F.3d at 1347 (Newman, J. concurring.). However, this case merely states the oft-stated proposition that claims that are broader than the application's disclosure will not be allowed. *Id.* And, finally, cases have stated the proposition that there is, at least with respect to combination patents, no "essential" element. *Aro Mfg. Co. v. Convertible Top Replacement Co.*, 365 U.S. 336, 345, 128 U.S.P.Q. (BNA) 354 (1961) ("[T]here is no legally recognizable or protected "essential" element, "gist" or "heart" of the invention in a combination patent.")

In summary, though the validity of the "omitted" or "essential" element test is in doubt, this application does not even fit the test. The application discloses more than enough information to allow one of ordinary skill in the art to practice the invention. The elements which the Examiner says are omitted from the claims are certain of the variable ways to accomplish the defined steps of the invention. Given the language of the MPEP section, and the cases cited, the present claims should not be rejected based upon omitted essential elements. Applicants believe that this rejection should be reversed.

In response to the Examiners statement that "it is unclear from the claim language how a cw mode-locked laser pulse is generated with the claimed steps," the Applicants respond that the specification provides a clear description of how cw mode-locked laser pulses are generated using this invention. Claims are not required to provide every detail for implementing an invention, but only the necessary elements of the inventive process, because the steps cited by the Examiner are well known variants to those skilled in the art. To require the Applicants to limit their claims to a particular selection of alternative incidental steps would deny them of the breadth of protection which the law requires. Applicants request that this rejection be withdrawn.

35 U.S.C. 102 REJECTION

The examiner rejected claims 22-28, 33 and 34 as anticipated by Wayne. The Examiner states that Wayne discloses a method of generating laser pulses comprising generating Q-switched mode-locked laser pulses (col. 4, line 66- col. 5, line 27; abstract) and suppressing q-switching (col. 6, lines 28-50; abstract). The Examiner also states that the method disclosed by Wayne is a "method of generating laser pulses in a continuous wave mode-locked fashion (abstract). The Examiner states, however, that this limitation is not given patentable weight because the body of the claim does not support a cw mode-locked laser pulse, i.e., there is not a claimed step to manipulate any structural feature of the invention to generate a cw mode-locked laser pulse.

As to the final point raised by the Examiner, the applicant has added new claims in this amendment which add to the steps of the claims (as opposed to the preamble alone) the generation of cw mode-locked laser pulses. Thus, this element of the rejection should not apply to these new claims.

As to the anticipation rejection itself, by its own terms, the Wayne reference teaches a Q-switched laser which is cavity dumped, not a cw mode-locked laser. Nowhere does Wayne teach or suggest a cw mode-locked laser. The only mention of CW is in the abstract, where Wayne describes the basic type of laser used as his starting point. He then immediatly states what he does with this laser...he converts polarization states to Q-switch the laser, then terminates the voltage near the maximum Q-switch buildup to convert the polarization to cavity dump an output pulse. Simply stated, this is not a cw mode-locked laser, and it does not produce cw mode-locked laser pulses. Moreover, the Wayne patent never states that it produces cw mode-locked laser pulses. Nor does the Wayne patent teach the suppression of Q-switching to produce cw mode-locked pulses. Rather, Wayne teaches cavity dumping at the peak of the intracavity Q-switch buildup (col. 6, ln. 41-43) to dump the cavity to provide an optical pulse. This is the antithesis of cw mode-locking. Applicants request that this rejection be withdrawn.

35 U.S.C. 103 REJECTION

The examiner rejected Claim 25 as obvious over Wayne in view of Hordvik. As stated above, Wayne does not meet the essential limitations of the parent claim as suggested by the

Examiner. Hordvik does not correct this fundamental void in the cited art. Rather, Hordvick teaches only a Q-switched laser with stretched pulses, not a laser in which cw mode-locked energy is generated from Q-switched mode-locked pulses. The most that Hordvick could add to Wayne's disclosure is the stretching of pulses, not the generation of cw mode-locked pulses. Applicants request that this rejection be withdrawn.

Respectfully submitted,

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